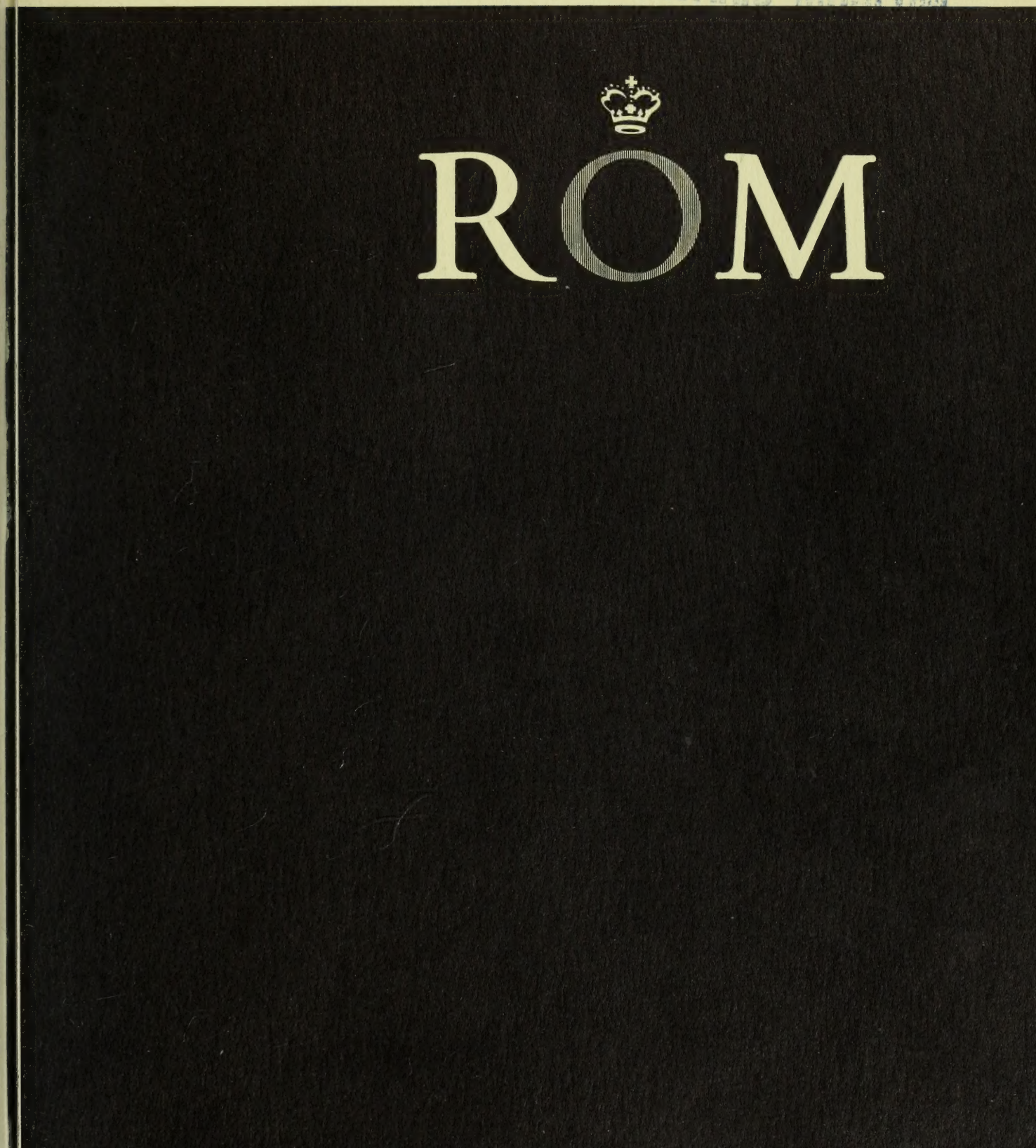
LIFE SCIENCES DIVISION - CONTRIBUTION 55

E. J. CROSSMAN

The Grass Pickerel
Esox americanus vermiculatus LeSueur in Canada

ROYAL ONTARIO MUSEUM - UNIVERSITY OF TORONTO



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Introduction

Although LeSueur's original description of the grass pickerel, as *Esox vermiculatus*, appeared in the 18th volume of Cuvier and Valenciennes in 1846, this species has received little attention. The three larger North American members of the family Esocidae, as a result of their commercial and sport values, have been extensively studied. The biology of the two small pickerels has been largely ignored and the literature contains little other than references to their presence in various areas and comments on the supposed similarity between their biology and that of the pike, *Esox lucius* Linnaeus. The grass pickerel and the redfin pickerel *Esox a. americanus* Gmelin are generally considered too small to be of much value. Their size and the somewhat unattractive nature of their habitat preclude the likelihood of their becoming important sportfishes.

The earliest record of capture of the grass pickerel in Canada is that of a large young taken in 1899 by Professor Jacob Reighard in Long Point Creek, Norfolk County, Ontario (Hubbs and Brown, 1929). The earliest published record is, however, that of Fowler (1915) reporting on a 1904 collection by W. S. Ray in Sparrow Lake, Muskoka District, Ontario. Fowler's record is the earliest published unless the fish that Nash (1908) records from Toronto as *Lucius reticulatus* (= *Esox niger*) was in reality *Esox a. vermiculatus*. Nash's colour and size descriptions fit *E. niger* but there have been no subsequent reports of either species from that area.

This paper is based principally on 543 specimens collected in Jones Creek, Leeds County, Ontario (see Fig. 3) in the summer of 1960 and is intended to document something of the biology of this fish in Canada. Data from these specimens are supplemented by information on distribution and biology gained from specimens previously collected in Canada and housed in various museums.

Many of the analyses were carried out on specimens which had been fixed in 10 per cent formalin, washed out in water and then stored from three to six months in 65 per cent alcohol. Lengths and weights, however, were determined immediately after capture. Six per cent of the specimens were captured in fixed gear such as stream fences, gill nets and fyke nets; 80 per cent were taken by seining, and 14 per cent with rotenone. Total length (T.L.) was used for small fish ($<$ 70 mm.) since the fork in the tail is insignificant within that size range.

The body patterns of adults and young are shown in Fig. 1. As in all esocids there is considerable change in the pigment pattern of this species from young to juvenile to adult. For young-of-the-year in June (45 mm. T.L.) the most noticeable pigment is a golden dorsal stripe from the tip of the snout to

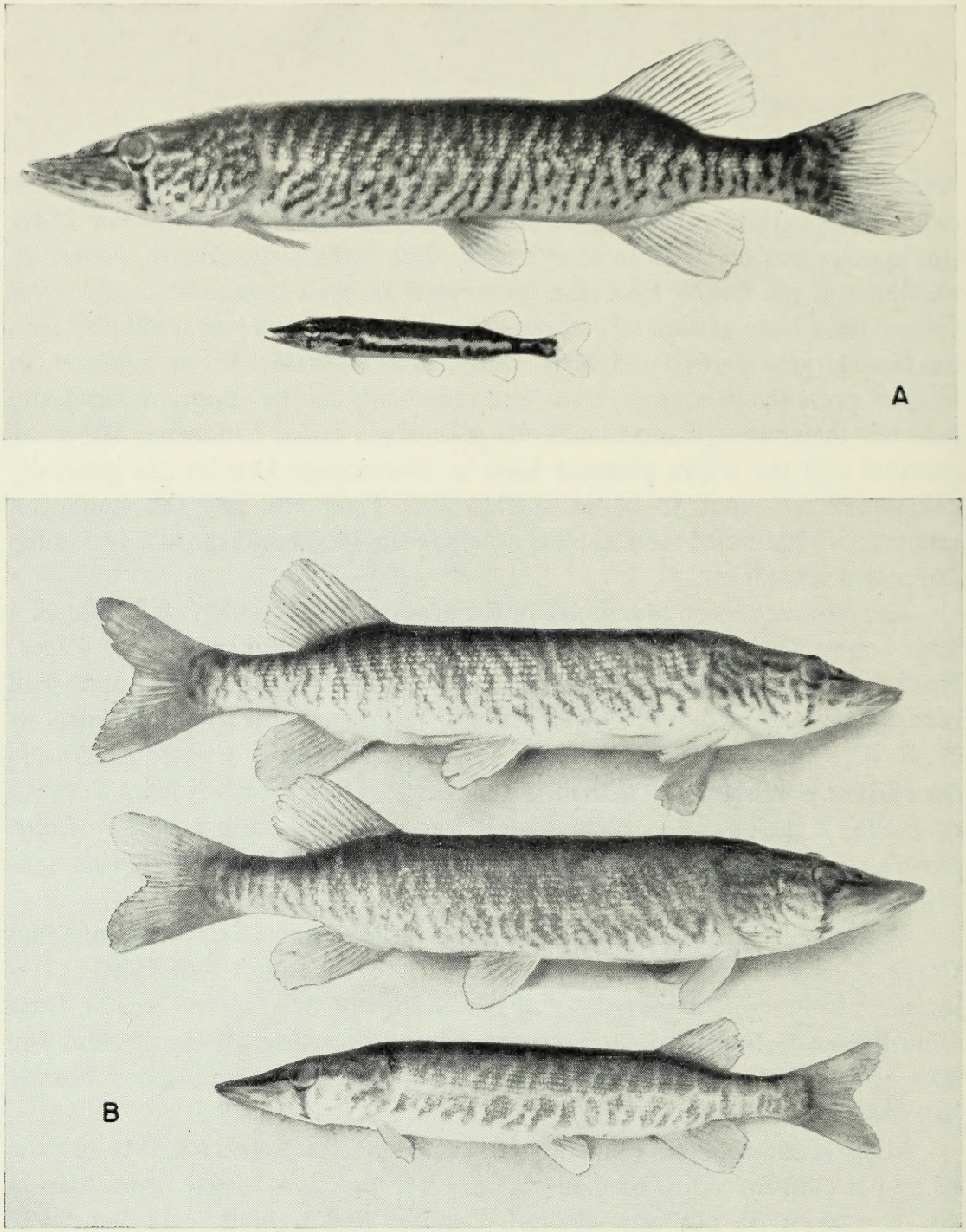


Fig. 1. Body pattern of grass pickerel *Esox americanus vermiculatus.*

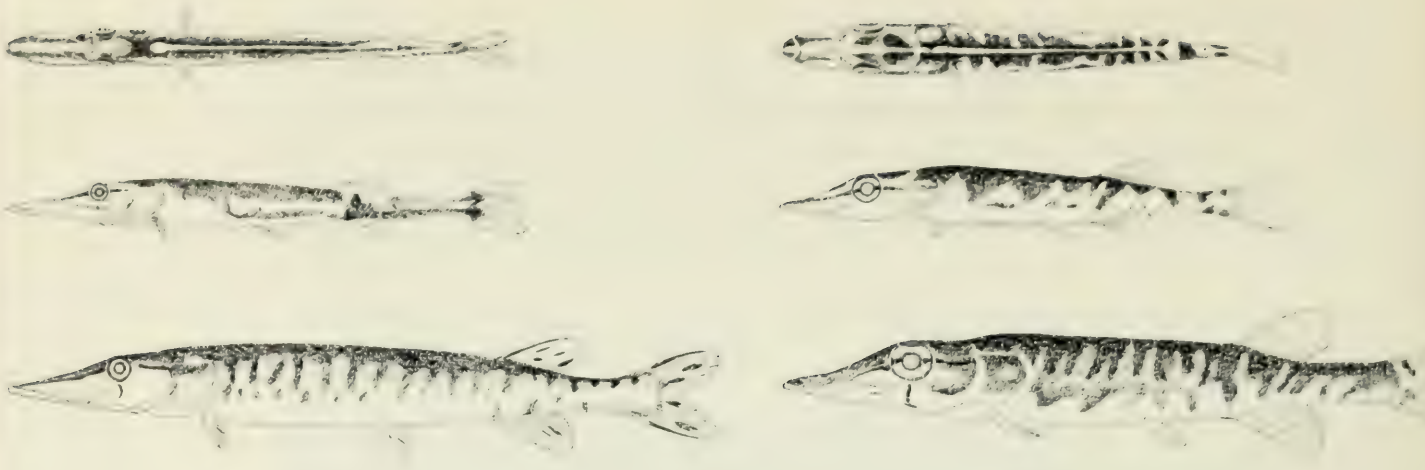
A. Typical adult (254 mm. or 10 inches F.L.) and young-of-the-year (102 mm. or 4 inches F.L.) in early October.

B. Two adults (254 mm. F.L.) and one sub-adult (216 mm. or 8.5 inches F.L.) showing variability in pattern and change with increase in size.

the origin of the dorsal fin (see Fig. 2). Often this is all that can be seen of the stationary young fish in the water. The dorsal surface and the upper half of the sides, above the lateral line, are uniformly brownish to olive-green. Below this is a narrow band of green-gold pigment from the operculum to the caudal peduncle. This is followed by a narrower black line and then another band of bright gold. The ventral surface is white. The operculum has a golden band about one half the width of the orbit bordered by two narrow black lines. The upper, narrow, black line is continuous through the centre of the eye and to the end of the snout, as is the golden band but not the lower black line. The remainder of the circular iris is golden and the pupil is round and black. The dorsal edge of the upper jaw has a narrow band of black, complete except where the dorsal gold stripe extends along the midline to the tip of the snout. The dorsal edge of the lateral surface and the lateral edge of the ventral surface of the mandible have narrow black borders. The branchiostegal apparatus is of a greenish hue. The dorsal edges of the orbits are rimmed with black. The suborbital bar is visible but not prominent at this size. The dorsal, anal, and paired fins are clear. The tip of the caudal is pale red, the base black and the caudal peduncle has a reddish tint.

In individuals larger than 50 mm. and less than 140 mm. the black lateral pigmented areas are broken by less pigmented patches creating a variable set of black dorsoventral bars. These bars are usually separated by dorsal and ventral extensions of a light green, lateral bar. These dorsal and ventral continuations of the lateral band extend almost to the middorsal line. It is the dark green to black pigmented areas which are the more obvious in life. The pattern represented by the unpigmented areas becomes more prominent in preservative. The golden, middorsal line ends at the eyes and disappears quickly after death. At this size the gold on the head disappears except for the iris, and the areas of black pigment, including the straight suborbital bar, become more pronounced.

The adult pattern which first appears at about 130–140 mm. is exceptionally variable. The lateral pattern consists generally of about 15–23 olive to black, wavy bars separated by the lightly pigmented extensions of the golden-green lateral band. The dorsal surface is a uniform vermilion green to dark green and the ventral surface a milky white. Adults retain the dorsal band but it is rusty brown and extends from the nape to the origin of the dorsal fin. Above and a little below the lateral line, the light areas separating the dark bars consist of flecks of green-gold pigment on a pale green field. These flecks are arranged in about 13 horizontal rows. On the head the dark colour of the dorsal surface extends to just behind the eyes and about one-quarter of the way down the side. The portion of the midorbital line anterior to the eye remains and is prominent. The suborbital bar is black, straight, vertical, slightly narrower at the bottom and very pronounced. There is a prominent black, vertical, bean-shaped spot on the operculum just above the longest area of that bone, and the lower half of this area has several black wavy lines. The lateral edges of both jaws have black borders as has the tip and to a variable extent the medial and lateral edges of the undersurface of the mandible. The leading edges of all fins are dusky to black, as is the trailing



ESOX MASQUINONGY

ESOX NIGER

ESOX A. VERMICULATUS

ESOX LUCIUS

ESOX A. AMERICANUS

Fig. 2. Comparative body shape and pattern of the young (50 and 100 mm. T.L.) of five species of *Esox*.

edge of the dorsal. The tips of the caudal and the small triangular patches at the base of each lobe are dusky.

An attempt was made to determine sex externally in this species as in the redfin pickerel (Crossman, 1962) by using the submandibular pigment concentration. The pigment was so variable and diffuse in the grass pickerel that no consistent results were obtained.

MORPHOLOGY

The body of this species, as in all those of the family, is elongate and is almost cylindrical in cross-section anterior to the dorsal fin. The grass pickerel is less compressed laterally than the larger esocids. In cross-section the dorsal surface of adults is flat to slightly concave anteriorly. At all sizes the grass pickerel appears more rotund and thicker than young pike (*E. lucius*) or muskellunge (*E. masquinongy*), with which they are often confused. The single soft dorsal fin which is immediately over the anal fin is somewhat square in outline but the anal has a more rounded tip. The paired fins are rounded and situated low on the body. The head is large and the snout extensive, broad and often likened to a duck's bill. The dorsal surface of the snout is slightly concave (in the long axis) between the raised orbits and the tip of the snout. The snout is less concave than that of the larger pikes but more so than that of the closely related redfin pickerel. The mouth is large and heavily armed with teeth on the jaws, roof of the mouth and tongue. Those on the tongue are fine and weak. The teeth slant inward and back and facilitate grasping and swallowing prey. As in the other species there are also patches of denticles on the gill arches. The whole area of the cheeks and opercula is scaled to a varying degree.

The statements below give meristics for the species over the whole of its limited known range in Canada. The counts are based on 80 specimens which include 10 from Jones Creek. Table I gives a frequency summary for these counts for the Jones Creek population.

The anal fin has 16–18 rays (all rays counted), the dorsal 17–21, the pectoral fins 14–15, and the pelvic fins 9–10. The modal submandibular pore count was four on each side but there were rare single side counts of three and five. The vertebral counts ranged from 42 to 47 with a mean of 44.9. Lateral-line scale counts ranged from 93 to 118 with a mean of 102.8 scales (all scales counted). Total branchiostegal ray counts ranged from 19 to 27 and single-side counts from 9 to 14. There were 23 combinations of numbers of anterior and posterior rays (Crossman, 1960) ranging from 3+8:5+7 to 6+8:6+7. The mode was the symmetrical count 5+7:5+7 and the count 6+7:6+7 was the next most frequent symmetrical arrangement. All non-symmetrical combinations having a frequency greater than one contained at least one 5+7 combination, and the most frequent of these were 4+7:5+7 and 5+7:6+7. This species shows the greatest tendency in the family toward the unusual arrangement of the right branchiostegal membrane overlapping the left. (*E. lucius* appears to be invariably left-sided.) There were seven

TABLE I. FREQUENCIES OF COUNTS FOR *Esox a. vermiculatus* FROM JONES CREEK, 1960

												N	$\bar{X}$
SUBMANDIBULAR PORES (Right : Left)													
3 : 4	4 : 3	4 : 4	4 : 5	5 : 4								50	–
2	1	43	3	1									
BRANCHIOSTEGAL RAYS													
Total (2 sides)	22	23	24	25	26	27						50	24.2
	2	8	22	14	3	1							
Single Side	10	11	12	13	14								
R	1	5	36	7	1							50	12.0
L		5	31	14								50	12.4
LATERAL LINE SCALES													
97	98	99	100	101	102	103	104	105	106	107			
4	4	2	3	3	2	5	3	2	1	–			
108	109	110	111	112	113	114	115	116	117	118		50	105.5
4	2	2	3	4	1	–	1	1	2	1			
VERTEBRAE													
42	43	44	45	46	47							29	44.9
1	1	8	12	5	2								
FIN RAYS													
	9	10	14	15	16	17	18	19	20	21			
Pelvic	18	7										25	9.3
Pectoral			10	15								25	14.6
Anal					1	9	15					25	17.6
Dorsal							1	15	8	1		25	19.4

right-sided individuals in 50 analysed for branchiostegal characteristics. This is 14 per cent within one population, and double that noted in an interpopulation count (Hubbs and Hubbs, 1945).

NAME

In the literature the grass pickerel has been referred to as *Esox vermiculatus*, *Esox americanus vermiculatus* and *Esox americanus*. Legendre, after studying specimens of the grass pickerel and the redfin pickerel, considered the grass pickerel a subspecies of the coastal form or redfin pickerel. He referred to the grass pickerel by the subspecific name *E. a. vermiculatus* (Legendre, 1952) but did not publish the evidence for his decision. This status has been accepted by many recent authors and rejected by others. It was accepted for the American Fisheries Society Names List (Bailey, 1960) and it is on that basis that the subspecific designation is used here. A study, by the author, of the relationship of the two pickerels is now underway and will be reported on later.

The accepted common name (loc. cit.) for *E. a. vermiculatus* is the grass pickerel. This species, in Ontario, is also known as the mud pickerel, little pickerel, pickerel, grass pike and mud pike. The common names in Quebec are le brochet vermiculé and le brochet de vase.

DIAGNOSTIC CHARACTERS FOR CANADIAN ESOCIDS

The following characters while not the simplest or fastest for field identification will be found to be the most reliable where two or more species of esocids may be encountered.

Within the adult size range of *Esox a. vermiculatus* (6–12 inches) the general robust shape and the wavy, thin, dark bars of the flanks should separate it from juveniles of the larger species (*E. masquinongy*, *E. lucius* and *E. niger*) of the equal length. These juveniles will all be much thinner, more laterally compressed and the larger ones should possess the distinctive adult colour pattern of that species. Figure 2 shows body shape and pattern for the young of the various species. Since body shape and colour pattern of the grass pickerel and the redfin pickerel *E. a. americanus* are very similar in the young and the pattern is extremely variable at all times, these characteristics will not suffice to separate the two small pickerels.

Other characters such as most frequent branchiostegal ray arrangements, submandibular pore counts and snout length readily separate the small pickerels from the larger esocids. Comparisons of these are given in Table II. The most useful means of separating the two small pickerels in Canada are those given by Legendre (1954:35) as follows:

	Nape to Dorsal Origin / Snout Length	Number of Notched Scales Between Pelvic Fins	Snout Shape
E. a. vermiculatus	$<4\frac{1}{2}$	<5	more concave
E. a. americanus	$>4\frac{1}{2}$	>5	convex

TABLE II. Characters to Separate Esocids in Canada

	Branchiostegal Rays*	Submandibular Pores	Total Length mm. / Snout Length mm.	
			$\bar{X}$	Range
E. masquinongy	8+10 (8+9)	12–20	8.14	7.31–8.95
E. lucius	7+8 (6+8)	9–11	8.07	7.31–8.95
E. niger	6+9 (7+9)	9–11	7.03	6.23–7.51
E. a. americanus	6+8 (5+8)	7–9	8.71	8.23–9.18
E. a. vermiculatus	5+7 (6+7)	7–9	8.68	8.20–9.57

*The most frequent and the next most frequent single-side counts are shown.

North America

The total distribution of grass pickerel extends, in the Mississippi drainage, from south-eastern Wisconsin and southern Michigan (below Saginaw Bay), south through eastern Iowa (rare), southern Missouri, the south-east corner of Oklahoma to eastern Texas and as far west along the Gulf coast as the Brazos River. Populations in north-central Nebraska are probably relicts. It extends east through the gulf States probably to some point in Georgia. It follows the Mississippi drainage northward, west of the Appalachians to western Pennsylvania. It is found in western New York and northward to southern Ontario and the Montreal region of Quebec. There are isolated populations in south-eastern Washington State resulting from introductions around 1888 (pers. comm. D. Earnest). This species was also introduced into El Paso County, Colorado, in the 1930's (pers. comm. L. E. Riordan). Smith (1896) reported that this species, identified by Jordan, was taken from Lake Cuyamaca, near San Diego, California in 1892.

The northern limit of distribution corresponds rather closely to the 70° F. July isotherm.

Canada

In Canada distribution of the grass pickerel is very limited (Fig. 3). It occurs in Lake St. Clair drainages, tributaries of Lake Erie and the Upper Niagara River. Sporadic populations occur in Lake Ontario drainages between Belleville and Kingston but it is apparently absent from Hamilton to Belleville. It is locally abundant in some creeks tributary to the St. Lawrence River, from Gananoque east to the confluence of the St. Lawrence and Ottawa rivers (Lake St. Louis) near Montreal. It was reported to be absent from collections made in streams from Morrisburg to Cornwall (Toner, pers. comm.). From extensive collections made by the author within the possible range in Quebec it would appear to be mainly limited to the north shore of the St. Lawrence and the area west of Montreal, although it has been reported from the mouth of the Chateauguay River and a stream near Woodland both on the south shore of Lake St. Louis (Cuerrier *et al.*, 1946). There is an isolated population in the Severn River (tributary to Georgian Bay) in the Muskoka District of Ontario. This population possibly represents an inadvertent introduction. They may have been introduced there many years ago with, or as, muskellunge of Bay of Quinte (Lake Ontario) origin. It is not impossible, however, that the Severn River population represents a relict northern limit of extension up the Trent System. *E. a. vermiculatus* possibly has disappeared from the larger streams below Lake Simcoe in the face of competition from *E. lucius* and *E. masquinongy* much as *E. lucius* displaces *E. masquinongy*.

Radforth (1944) stated that *Esox vermiculatus* would "appear to have entered Ontario waters from only the Mississippi Valley centre probably utilizing both the Chicago-Ubly and Fort Wayne connections and have succeeded in dispersing beyond the limits of other Mississippi derivatives". Possibly the populations in the Niagara River and eastern Ontario are of New York origin rather than an extension of those entering Ontario from

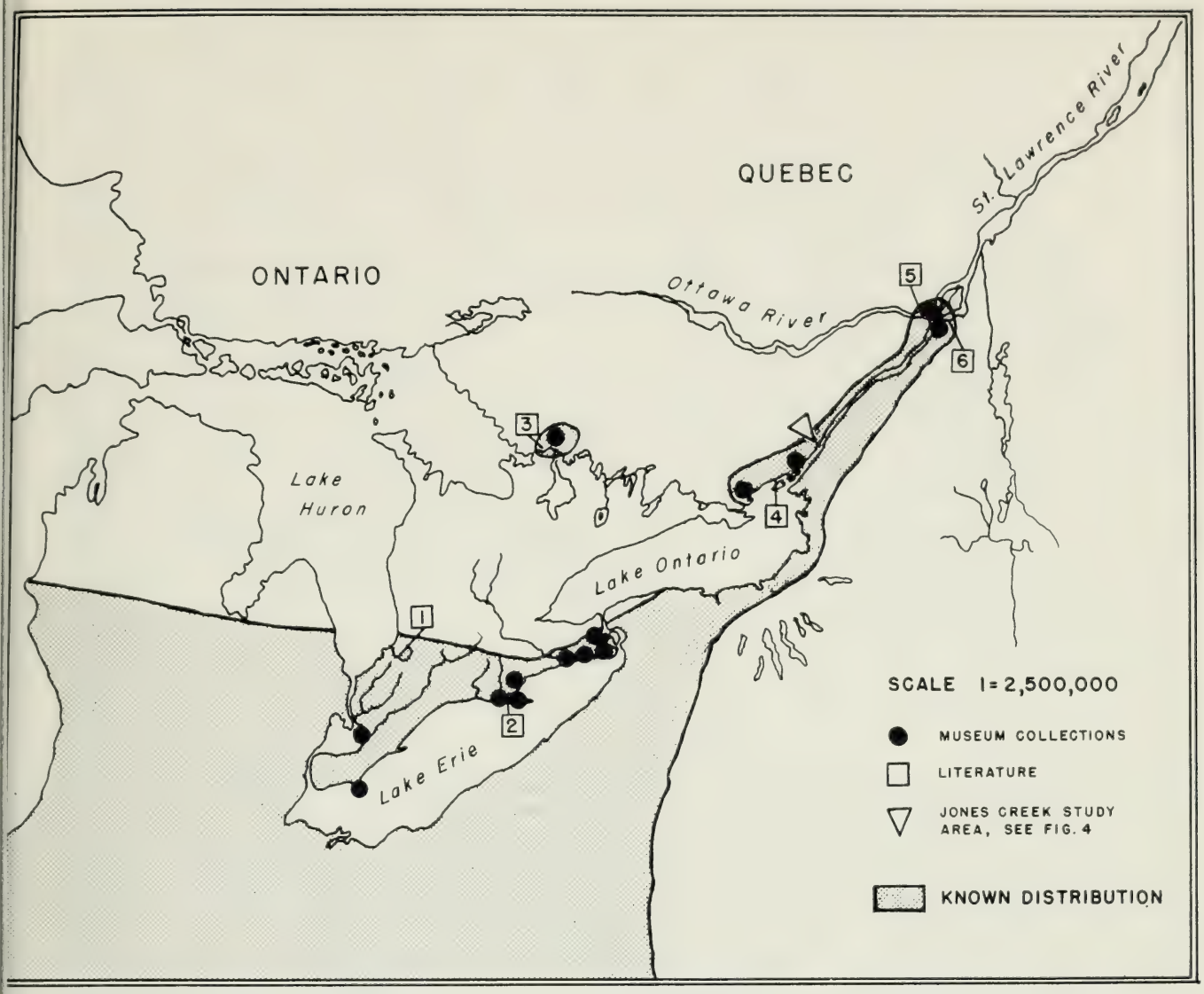


Fig. 3. Distribution of *Esox a. vermiculatus* in Canada and contiguous area of the United States.

the southwest. There is some slight morphological evidence to suggest this, and to suggest that the Severn River population is closer to the eastern than to the western populations. Table III shows some morphological characters which may substantiate this.

TABLE III. Average Figures for Various Body Proportions for Several Populations of *Esox a. vermiculatus*

General Area	No. Spec.	Total Length / Head Length	Total Length / Snout Length	Occiput to Dorsal Origin / Snout Length
Lake St. Clair	3	3.20	7.63	3.36
E. Lake Erie	19	3.42	8.23	3.48
W. Lake Erie	23	3.18	7.96	3.22
Niagara River	10	3.65	8.98	3.92
Severn River	10	3.58	8.61	3.62
E. Lake Ontario	5	3.65	8.98	3.83
St. Lawrence R.	2	3.50	8.62	3.89
Quebec	3	3.45	8.15	3.55

The western and central Lake Erie populations probably result from a post-glacial advance as described by Radforth (1944). It is postulated that the eastern Lake Erie and Niagara River populations resulted from spread westward across the narrow Niagara River. The eastern Lake Ontario and St. Lawrence populations in Canada were probably also the result of the spread of this species across the St. Lawrence River after populating the lowland margin of the south shore of Lake Ontario. While they are still absent from large sections of the north shore of Lake Ontario they have long been known from various points along the south shore, west of Rochester (Evermann and Kendall, 1902).

The narrow, weedy St. Lawrence forms a much less formidable barrier to this species than do lakes Erie and Ontario. The Deseronto population is then considered to be a westward extension of this northward expansion across the St. Lawrence.

Regarding distribution within a single stream such as the study site of Jones Creek (see Fig. 4) the species populates all suitable areas from an impassable falls near the mouth to the headwaters of the creek.

HABITAT

In Canada the grass pickerel is a resident of small, slow moving, muddy, heavily vegetated, rarely somewhat acid lowland streams, and the small pond-like expansions of these streams or overflow ponds of larger streams. More rarely it is found in quiet weedy bays of lakes. The tolerance level of oxygen concentration for this species has been reported to be 0.4–0.3 ppm. in Michigan (Cooper and Washburn, 1949). The final preferred temperature, as determined from specimens from the eastern Ontario population, was 26°C. or 78°F. (Berst and Lapworth, MS.). The cruising speed of the grass pickerel increases with increasing acclimation temperature (Schultz and Rigler, MS.). Thus its physiology enables it to be very active, successful and to withstand the very high water temperatures, drastic decreases in water level, and minimum flow conditions typical of these streams.

Population size or production figures are sometimes indicative of the success of a species in its environment. No such figures are available from the Jones Creek work but figures of 0.8 fish per acre (Carbine and Applegate, 1948) and 101 and 111 fish per acre (Eschmeyer and Clark, 1939) have been given for Michigan and Ohio. The Michigan lake had 369 grass

Key to Literature References on Distribution Maps

1. Ausable River, Lambton Co. (Scott, 1954); 2. Long Point Creek, Norfolk Co. (Hubbs and Brown, 1929); 3. Sparrow Lake, Muskoka District (Fowler, 1915); 4. Kingston Harbour (Belle Isle) and Grassy Creek, Frontenac Co.; Gananoque Lake and River as high as the falls at Lyndhurst, Wiltse Creek, Leader Creek, Escott Creek, Leeds County (Toner, 1943); 5. Lac des Deux Montagnes and rivers in the area (Cuerrier, 1947); 6. Bay and stream of de Brussy, Madore Bay (Ile Perrot), St. Jean River (Woodlands) and Chateauguay River near the mouth (Cuerrier *et al.*, 1946); 7. Mud Creek, Maple Grove Creek and St. Lawrence River, Leeds Co. (Toner, 1937); 8. Grippen Lake, Leeds Co. (Toner and Edwards, 1938).

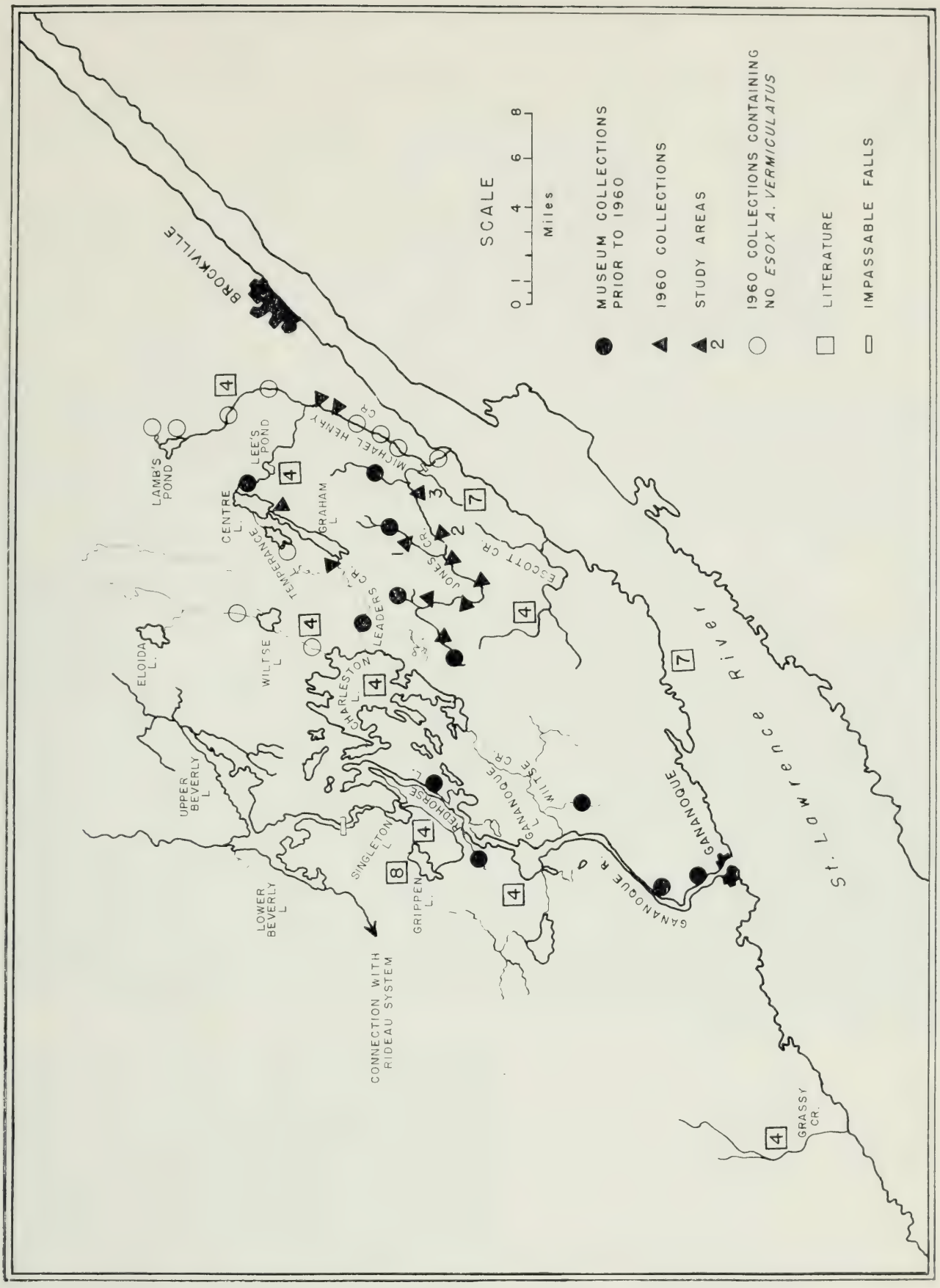


Fig. 4. Map of the study site showing distribution of *Esox a. vermiculatus* in Jones Creek and surrounding area.

pickerel in a 14.8 acre lake and 81.2 per cent of these were young-of-the-year.

The Jones Creek Study site (Figs. 4 and 5) is a typical habitat. The system consists of one and one-half miles of stream one-fifth mile wide below an impassable falls (20 feet) and two branches, 5 feet to 20 feet wide, each about 10 miles long. One branch only, Michael Henry Creek, is accessible to fish moving in from the St. Lawrence River since it enters Jones Creek below the falls. Within Jones Creek above the falls three Study Areas were established from which most of the specimens and data were obtained. Mean depth in June was 3.5 feet and in August 1.5 feet. Maximum depth was 5.5 feet in the pond of Study Area 1 in June. The depth varies drastically over the summer. In a two-day period in August, 1961 it dropped 11 inches and rose by as much in a two-day rain. In 1960 it dropped 15 inches through the month of June and then with minor changes with rain, remained at this level through the remainder of the very dry summer. As a result the creek dried up in many places and left the fish isolated in only the deeper pond expansions. These ponds were from 15 feet to 80 feet in diameter and in the late summer of 1960 varied in depth from three inches to three feet. The flow of water varied from one-half ft./sec. in June to no visible movement in August. The maximum water temperature of 84° F. was recorded on July 23, 1961 in Study Area 1. The water temperature was 76° F. as late as September 9 in 1960.

The water was stained brown but the pH of Study Area 2 was 7.65. The pH for other habitats of this species were as follows: Point Pelee (western Lake Erie) 8.32, Deseronto (eastern Lake Ontario) 7.85 and the Severn River 6.26. The water in most sections of Jones Creek was heavily silted from runoff over ploughed land or as a result of cattle breaking down the banks when drinking.

The bottom was largely mud with some areas of clay and some of rock and mud. The banks were extensively undercut and the bottom littered with logs and branches.

Over much of its length the stream ran through pasture land and had woody or shrubby margins (Study Areas 2 and 3) but Study Area 1 was a low, marshy section. The common submerged plants were *Elodea, Ceratophyllum* and *Potamogeton*. The common floating and emergent vegetation consisted of *Nuphar*, *Pontederia* and *Polygonatum*. Table IV lists the aquatic vegetation of Study Areas 1 and 2 and Michael Henry Creek. The scale of abundance (1–5) holds only within the area considered. Some areas of the stream were so choked with emergent and submergent plants and algae in August that it was impossible to push a boat through or to seine.

In all, 24 species of fish were taken with *E. a. vermiculatus* in Jones Creek. These were as follows: *Umbra limi*, *Esox lucius*, *Catostomus commersoni*, *Moxostoma valenciennesi*, *Cyprinus carpio*, *Notemigonus crysoleucas*, *Notropis bifrenatus*, *N. cornutus*, *Pimephales notatus*, *P. promelas*, *Semotilus atromaculatus*, *S. corporalis*, *Ictalurus nebulosus*, *Ambloplites rupestris*, *Lepomis gibbosus*, *Micropterus dolomieui*, *M. salmoides*, *Perca flavescens*, *Etheostoma flabellare*, *E. nigrum*, *Percina caprodes*, *Eucalia inconstans*. The species most commonly associated with the grass pickerel

Fig. 5. Photographs of Jones Creek showing the habitat of *Esox a. vermiculatus*.

A. Study Area 1.
B. Study Area 3.
C. Study Area 2 on June 1, 1960.
D. Study Area 2 in mid August showing change in water level.
E. A pond expansion in a rocky section of the creek which contained a substantial population of grass pickerel in August 1960.

TABLE IV. A List of the Vegetation of Various Sections of Jones Creek, August 1961

SPECIES[a]	Study Area 1	Study Area 2	Michael Henry Creek
FLOATING AND EMERGENT			
Alisma triviale Pursh		*	
Armoracia aquatica (Eat.) Wieg.			*
Callitriche palustris L.		2[b]	
Eleocharis calva Torr.			*
Equisetum fluviatile L.	*		2
Nuphar variegatum Engelm.		5	*
Lemna minor L.	*	*	
Nymphaea odorata Ait.		*	*
Polygonatum coccineum Muhl.		3	
Pontederia cordata L.		4	
Potamogeton amplifolius Tuckerm.			*
Potamogeton natans L.	5	*	
Potamogeton nodosus Poir.			5
Sagittaria latifolia Willd.		*	*
Rumex verticillatus L.		*	
Scirpus validus Vahl var. *creber* Fern.	*	*	5
Sparganium androcladum (Engelm.) Morong		*	
Spirodela polyrhiza (L.) Schleid.		*	
Veronica anagallis-aquatica L.		1	
SUBMERGED			
Elodea canadensis Michx.		3	*
Ceratophyllum demersum L.	3	4	5
Chara sp.			*
Eleocharis sp. (submerged, sterile)		*	
Lemna trisulca L.		*	
Najas flexilis (Willd.) Rostk. and Schmidt			*
Potamogeton obtusifolius Mert. and Koch	5	5	*
Potamogeton zosteriformis Fern.	*	2	1

[a]Nomenclature of Gray's Manual, 8th edition.
[b]Relative abundance scale 1 (lowest) to 5 (highest).
*Only a few scattered plants.

was *Umbra limi* which was extremely abundant. No grass pickerel were captured in any section of the stream which did not contain mud minnows. *Catostomus commersoni*, *Notemigonus crysoleucas*, *Ictalurus nebulosus* and *Lepomis gibbosus* were the next most common associates.

Only in Michael Henry Creek, into which fish have access from the St. Lawrence, were *Esox lucius* and *Esox a. vermiculatus* found together. In this stream *E. lucius* inhabited the lower area; in one limited location the two were taken together and *E. a. vermiculatus* existed alone in about a mile of the mid-section of the stream. Above this point no esocids were found. The wide, deep section of Jones Creek below the falls appears to contain no grass pickerel but pike are abundant. Jones Creek is connected with the Charleston

Lake—Gananoque River system and this in turn, through Beverly Lake, is connected with Whitefish Lake of the Rideau system. Toner (1943) said that *E. vermiculatus* occurs as high in the Gananoque system as the [24-foot] falls at Lyndhurst. The Rideau system contains no grass pickerel but pike are abundant. In a stream habitat of the type described conditions are either unsuitable for *E. lucius*, or *E. a. vermiculatus* is so much better adapted that it displaces the pike. Wright (1918) discussing fish succession in streams stated that "in the more recent tributaries of . . . older streams both pike and grass pike occur and the former with the greater range . . . and (*E. lucius*) remains the longest in the oldest portions of a growing stream".

Usually the smaller grass pickerel (to 4 inches) were living in the vegetation of the stream and the larger ones were found in the pond expansions. They apparently move very little and only short distances to hunt for food or shelter in this weedy and well populated habitat. Fyke nets were set up in such a way as to close off the 100-yard-long study area to movement in or out. The fixed gear caught very few fish but seining between the fences seldom failed to catch a number of grass pickerel. When observed, grass pickerel were most often seen stationary and almost motionless in the vegetation of the shore line about three feet from shore facing shoreward. They were observed to remain in this position for periods of at least one-half hour without moving more than the amount necessary to maintain a horizontal position with the head slightly raised. When observed by light at night, fish two to three inches long were seen "hiding" or possibly holding position beside stones right at the shore in three to five inches of water. Larger pickerel were in the same position as in daytime. Pickerel caught in the beam of 6-volt lamp would at times remain motionless even after being touched with a stick but at any quick movement of the light they would dart away. Fry, extremely wary and fast moving in daytime, could be readily captured by hand at night when they were in the beam of the light.

SEX RATIO

The sex ratio of a random sample of 242 individuals from Jones Creek was 105 males and 137 females. This ratio differs significantly from a 1:1 ratio ($p = <.01$). A considerable part of the sample was made up of large adult fish. As will be shown below the larger and older individuals are females (see Fig. 7).

SPAWNING

Toner (1943) reported that spawning of this species was noted in Jones Creek on March 30, 1936 and that mud pike spawn as soon as the ice leaves the marsh. He also said that as far as could be ascertained they keep closer to shore than does *E. lucius* but have the same habits, a large female and several smaller males being associated over a patch of dead vegetation. McNamara

(1937) said that male grass pickerel are the first fish to proceed up a stream after the ice has gone. They are followed by the females and spawning takes place in temporary flood plain marshes. The literature contains no account of spawning behaviour of this species.

No observations of spawning were obtained in the present study. On a reconnaissance trip to the site on April 26, 1960, the water temperature was 46° F. and no esocids or other fish were seen. Only one *Lepomis gibbosus* and one *Notemigonus crysoleucas* were taken overnight in a fyke net set over a suitable spawning area. A local resident said that the ice had gone from the creek two weeks earlier but that they had seen no fish as yet. The water temperature reached 50° F. on May 4, 1960. Young-of-the-year caught June 1, 1960, when the study actually began, ranged in length from 26–36 mm. T.L. This would indicate that spawning had probably taken place at least a month earlier, in late April to early May when the water temperature was in the range recorded for the initiation of spawning of other esocids (46°–54° F.). A ripe female was captured in a tributary of the Niagara River on April 5, 1958. The size range of young caught in Jones Creek after June 1 indicated that the spawning was over before June 1 and that the spawning period was not of long duration.

While the grass pickerel, like the other esocids, can be classified as a spring spawning fish, there is evidence that under certain conditions at least some individuals spawn in the fall. Lagler and Hubbs (1943) reported two incidents of fall spawning in this species in Michigan. They reported on young collected in November of 1941 which were comparable in size to young collected in June.

On October 16, 1960, a collection of 14 grass pickerel from Study Area 1 contained eight large specimens (184–240 mm. F.L.) and six smaller specimens (33–77 mm. T.L.). The two smallest were 33 mm. and 42 mm. T.L. and resembled, in size and degree of development, young captured on June 1, 1960. Scales of these smallest October specimens showed 6 and 12 circuli as opposed to 26–39 circuli for the four other individuals under 100 mm. in length. Young of comparable size caught in June had three and five circuli (see Fig. 6). The average number of circuli on the scales of ten fish under 100 mm. long on July 28 was 22.6. If the smallest individuals caught in October were of spring origin and had grown slowly it is likely that their scales in October would show as many circuli as larger fish of spring origin. It seems therefore that these individuals were hatched some time in September and that the slightly greater number of circuli is attributable to development in warmer water. (Maximum temperature April–May 46–66° F., September 71–76° F.). Additional evidence is the finding of a female in late August with ovaries distended with mature ova. At this time most females contained only immature ova.

Eggs of this species are broadcast, no nest is built (Scott, 1954), and the adhesive eggs cling to vegetation (inferred from Kendall 1917:39) on or near the bottom. It is inferred from development rates and other similarities to *Esox lucius* that eggs hatch in approximately 10 days to two weeks and in an additional 10 days to two weeks the yolk is absorbed and the young commence to feed actively.

Fig. 6. The total number of circuli on the scales of grass pickerel of various sizes.

Size at first spawning, as indicated by minimum fork length at which mature sex products were found, was 141 mm. (5.5 inches) for males and 157 mm. (6.2 inches) for females. It is possible, then, that both sexes are capable of spawning by at least two years of age. Maturity probably occurs at even smaller lengths.

McCarraher (1960) reported the occurrence of a hybrid in 1958 between the grass pickerel and the pike in Nebraska. The colour of the hybrid is that of *E. a. vermiculatus* and most other characters including length and weight are intermediate. It is his opinion (pers. comm.) that the hybrid represents the result of the mating of small, male *E. lucius* with large *E. a. vermiculatus* females. Ripe fish of both species were captured in gill nets within inches of each other. McCarraher also reported (MS.) that there is no evidence of sexual maturity of the hybrid, so it may be sterile.

EGG PRODUCTION

The average total volume of both ovaries for ten females of comparable length captured over the season was 1.76 cc. (0.4–4.8 cc.). This did not include females immediately ready to spawn. Greatest total ovarian volume noted for ripe females was 9 cc. for a female of 305 mm. F.L. As is characteristic of the small pickerels the ovaries contained eggs in three developmental stages (Crossman, 1962) as contrasted with the more usual two in *E. lucius* and *E. masquinongy* (Carbine, 1944; Crossman, 1962). Primary eggs, those most mature, are transparent, and amber to yellow in colour. These eggs averaged 1.4 mm. in diameter. The secondary and tertiary eggs

are successively smaller in size, pale yellow to white and opaque. Average diameters for secondary and tertiary eggs were 0.9 mm. and 0.3 mm. The primary eggs were randomly distributed over the mass of the ovary and surrounded, except laterally, by eggs in other stages of development.

Analysis of egg numbers, using ovaries of females beyond the spawning period does not yield satisfactory results. To distinguish between eggs in the three stages is difficult, and tertiary eggs are difficult to count or estimate accurately. Hence counts comparable to those for redfin pickerel (Crossman, 1962) were not obtained. The only reliable figures were mean values of 756.2 and 2380.0 for primary and secondary eggs (12 specimens). These correspond closely to figures given by Carbine (1944). He reported a total egg count of 15,732 for a 6.2-inch female *E. a. vermiculatus* from Michigan. This total consisted of 803 primary, 4,004 secondary and 10,925 tertiary eggs. While egg size in the two small pickerels is approximately the same, egg numbers differ. Egg number is almost twice as high in grass pickerel as in comparable sized redfin pickerel. This is true also of *E. lucius* as compared to *E. masquinongy*.

Female grass pickerel can apparently be readily stripped of their eggs and these can be reared artificially. Great difficulty is sometimes encountered from the eggs sticking to one another. The Pennsylvania Fish Commission in the past reared and distributed this species (Kendall, 1917).

FOOD

The diet of this fish, after the first few months of life, shifts from one of a variety of aquatic invertebrates to one consisting almost exclusively of fish and crayfish. The stomach contents of grass pickerel 20–50 mm. T.L. from Jones Creek, consisted of Cladocera, Amphipoda, Ostracoda, Odonata and less frequently Diptera, Plecoptera, Hemiptera and Isopoda. In the size range 50–100 mm. fish make their appearance but the diet is mainly made up of Trichoptera, Odonata and crayfish. The smallest grass pickerel which had preyed on fish was 54.0 mm. T.L. Over 100 mm. the diet is almost completely fish and crayfish but dragonfly nymphs appear occasionally. In large specimens which had eaten both fish and invertebrates the invertebrates were invariably dragonfly nymphs. The only additional items found in the stomach were bits of vegetation and small pebbles probably accidentally ingested. There was one tadpole and no frogs or other vertebrates, although tadpoles and small frogs were very plentiful in and about Study Areas. As high as 57 per cent of the stomachs examined for any month were found to be empty and all the October fish were empty. Table V summarizes the contribution of various items in the stomach contents of three size groups over the season. An attempt was made to catch grass pickerel in December (by angling and seining through the ice of Study Area 1) to determine winter food. This failed.

Examination of stomach contents of specimens from other Canadian locations revealed that the food pattern described above was general. Other invertebrates such as isopods and other fish were dominant in other localities.

TABLE V. Summary of Analysis of Stomach Contents of 387 Grass Pickerel from Jones Creek

Size Group	No. Examined	No. Empty	Crayfish				Immature Aquatic Insects				Bottom Organisms				Fish				Miscellaneous			
			A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
20–99	110	8	2	1.9	0.2	0.8	54	52.9	3.2	24.7	14	13.7	4.7	34.8	37	36.3	5.3	39.3	4	3.9	0.1	0.4
100–199	214	120	12	13.1	4.0	3.6	11	12.1	7.6	6.9					64	70.3	97.5	88.7	4	4.5	0.9	0.8
200–200	63	36	5	18.5	7.4	7.7	5	18.5	4.2	4.4					17	62.9	84.1	87.2	2	7.4	0.7	0.7

A. Number with that item in stomach.
B. Percentage that A was of the total number which contained food.
C. Total volume of that item for that size group.
D. Percentage C was of the volume of all foods eaten by that size group.

This food pattern is parallel to that reported by Rice (1942) for this species in Tennessee.

The greatest amount of food consumed by one grass pickerel (228 mm. F.L.) was 35 cc. in volume and 29 gm. wet weight.

The following is a list, in descending order of occurrence, of the species of fish found in the stomachs of grass pickerel from Jones Creek. The numbers in brackets refer to the number of individuals which had eaten that species (of a total of 387 examined): *Umbra limi* (89), *Notemigonus crysoleucas* (19), *Esox a. vermiculatus* (9), *Catostomus commersoni* (9), *Lepomis gibbosus* (6), *Notropis cornutus* (5), *Semotilus atromaculatus* (1), *Perca flavescens* (1), *Etheostoma nigrum* (1). (This list includes data from 35 specimens caught in 1961 and not included in Table V.)

In the western Lake Erie (Point Pelee) population, *Pomoxis nigromaculatus* was a prominent prey.

This is utilization of nine species, only five to any extent, of a total exploitable group of 22 other fishes. The dominance of *Umbra limi* and *Notemigonus crysoleucas* may be based on their greater abundance rather than on food selection by the pickerel. There is, however, some evidence of an association between the grass pickerel and the mud minnow. Almost invariably a collection contained both *Esox a. vermiculatus* and *Umbra limi* or neither species occurred in that collection. *Umbra limi* was the prey of five times as many grass pickerel as the next most frequent fish prey. These two facts seem to indicate some relationship beyond similar habitat requirements.

The largest fish eaten by a grass pickerel (228 mm. F.L.) was a golden shiner (*Notemigonus crysoleucas*) 134 mm. T.L. of a volume of 35 cc. and 25 gm. in weight. The greatest number of fish eaten by one individual was 30. These were *Umbra limi* 20–30 mm. T.L. and constituted only 7.0 cc. Rarely were there more than two fish in the stomach and in only two cases were the two of different species. There were no cases of gorging on fish as were reported for redfin pickerel (Crossman, 1962) even though fish were abundant and often confined in small pools with the pickerel. The Jones Creek data showed little association between size of pickerel and size or weight of fishes eaten. The grass pickerel would appear to be a random, predacious feeder.

In 387 specimens examined for food there were only nine cases of cannibalism in which grass pickerel 143 to 238 mm. F.L. had eaten a total of nine grass pickerel 40–70 mm. T.L. These attacks occurred uniformly over the period June 18, 1960 to August 11, 1960 and were not concentrated in the spring when the young first hatched. Possibly spatial separation of young adults as described under Habitat prevents frequent contacts and reduces cannibalism.

AGE AND GROWTH

The length frequency of 529 pickerel from Jones Creek is given in Figure 7. These data exhibit the sexual dimorphism of growth and the greater size

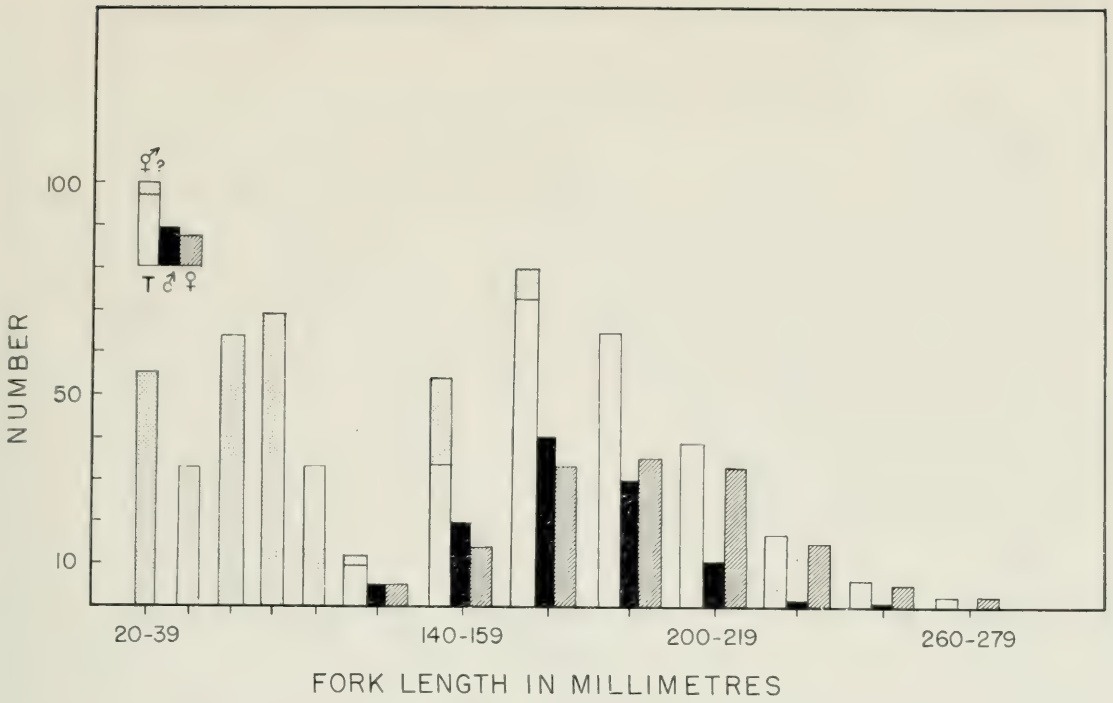


Fig. 7. Length frequency by sexes of the total Jones Creek sample (20 mm. intervals).

potential and longevity of females common in the family. In the size range above 180 mm. there is an increasing tendency for the number of females to exceed the number of males. The largest individual from Jones Creek was 269 mm. F.L. (285 mm. T.L.) or 10.6 inches F.L. A specimen from the Severn River population was 305 mm. F.L. (328 mm. T.L.) or 12.0 inches F.L. Van Oosten (1960) recorded the largest known grass pickerel as 14.8 inches. Trautman (1957) gives maximum length as 15 inches.

As in other species of the family, growth of the young is rapid. Hubbs (1921) gave the growth per day as 0.96 mm. "for a thirty-day period early in the first summer's existence" in Michigan. For the Jones Creek population the mean total lengths at mid-month intervals, for fish-of-the-year in 1960, were as follows: June, 24.6 mm.; July, 71.3 mm.; August, 77.7 mm.; and September, 87.9 mm. Growth in the first year approaches 100 mm.

Sexual dimorphism in growth is apparent in the length-weight relationship (Fig. 8) as all the longest and heaviest fish are females. The difference below lengths of 200 mm. appears less significant. The relationship is curvilinear over the range 25 to 269 mm. The heaviest individuals from Jones Creek weighed 192 gm. (6.8 oz.). The 12-inch pickerel from the Severn River population weighed 204 gm (7.3 oz. approximately). The 15-inch grass pickerel described by Trautman (1957) weighed 14 ounces.

Conversion factors for lengths for this species from 129 mm.–252 mm. F.L. over its whole Canadian range are:

F.L. to S.L. = F.L. $\times$ 0.8826

F.L. to T.L. = F.L. $\times$ 1.0582

While all length and weight data given were derived from specimens before preservation, parallel measurements were made before and after preservation in 10 per cent formalin to derive preservation corrections. For

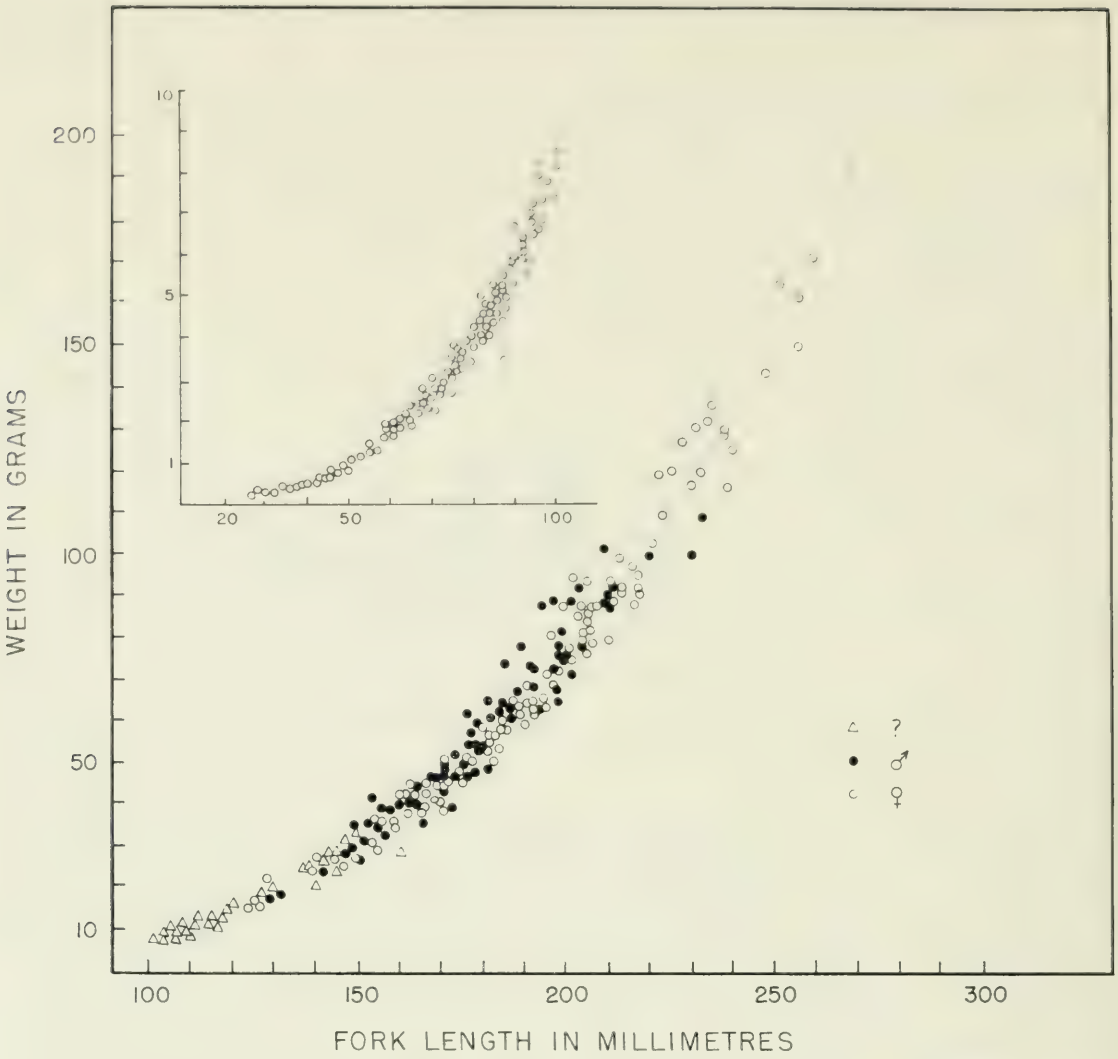


Fig. 8. Length-weight relationship of grass pickerel from Jones Creek. Inset shows relationship for young (sex unknown), under 100 mm. in length.

specimens over 130 mm. F.L., there was a decrease of six mm. in length over the first 15 hours and then no appreciable change after 21 days. The increase in weight with absorption of preserving fluid was at the rate of two gm. at the end of 15 hours of preservation, an additional two gm. after 48 hours and a further two gm., for a total increase of six gm., at the end of 21 days. There was no appreciable change after 21 days. Correction factors to live measurements after preservation in 10 per cent formalin are: length, F.L. mm. $\times$ 1.029 and weight, wt. in gm. $\times$ 0.940.

The age of 253 Jones Creek specimens 84–269 mm. F.L. was determined by the scale method. The only major problem encountered in this analysis was constituted by 10 individuals whose ages were very hard to interpret. It is assumed these are fall-spawned fish and this would explain the fact that they appear beyond the size range for that age. The age-length relationship is shown in Figure 9.

Ages in excess of those recorded in the literature for this species are indicated by the results given in Table VI. This is, however, apparently the first large series to be aged; the specimens are from the northern limit of this

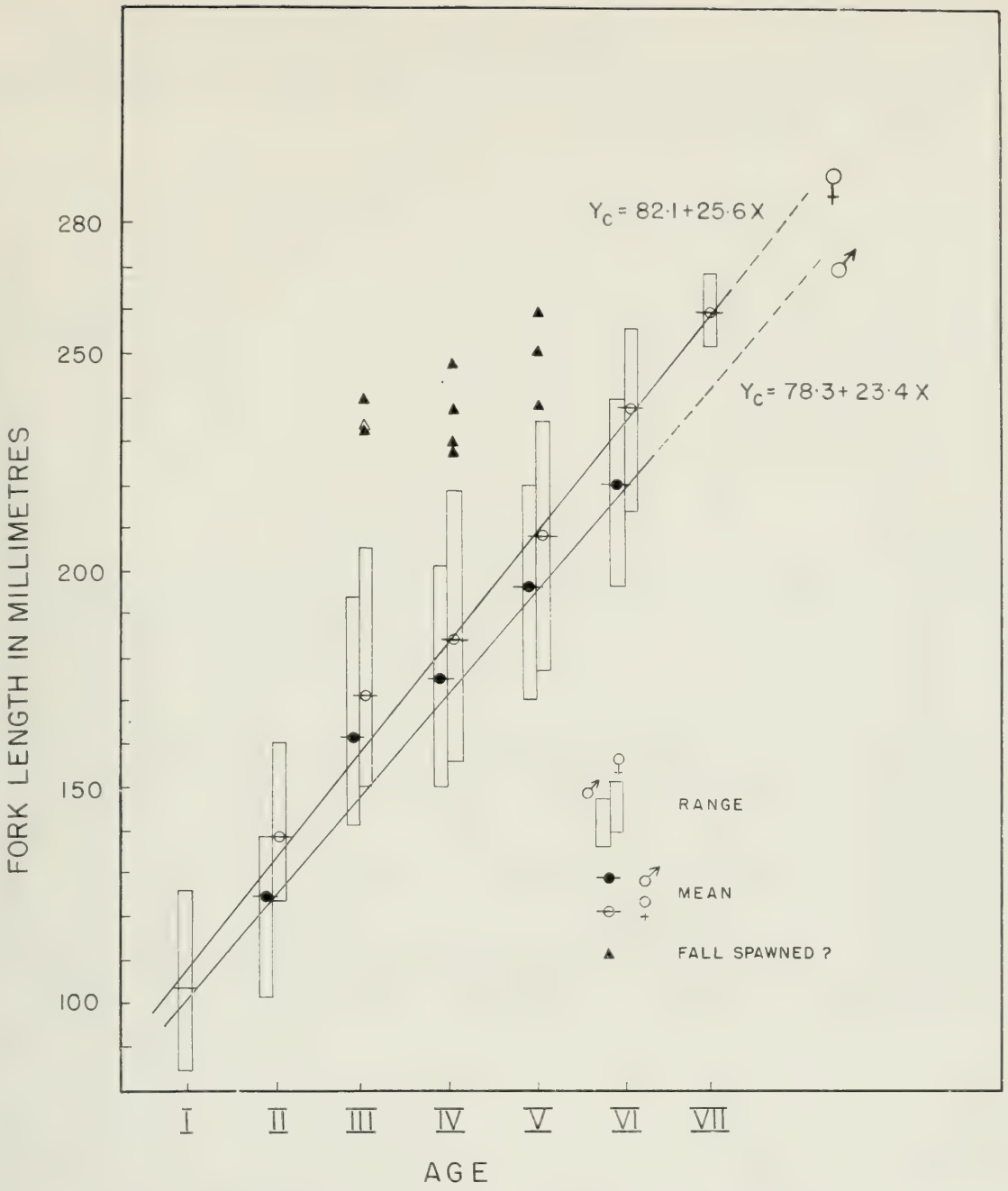


Fig. 9. Age-length relationship of grass pickerel from Jones Creek.

species and they do agree closely to those for the redfin pickerel given by Crossman (1962). The oldest individuals, females from 252 to 269 mm. F.L., were seven years of age. The growth appears continuous and the age-length relationship straight line in nature. The line for the females is above that for the males. (Yc ♂ = 78.3 + 23.4x; Yc ♀ = 82.1 + 25.6x.) The annual growth increment varies from approximately 30 to 14 mm. over the ages II–VII. In ages IV and above these data show a greater increment for females than for males.

The scale diameter-body length relationship was calculated for 170 grass pickerel from Jones Creek. The greatest long diameter of three scales from immediately below the origin of the dorsal fin of each fish were measured and the average for each fish calculated. Scales for pickerel 30–100 mm.

were measured with a calibrated microscope ocular; scales for those over 100 mm. were measured on projections of acetate impressions of the scales. The corrected diameters were plotted against total length of the fish and the results are shown in Figure 10.

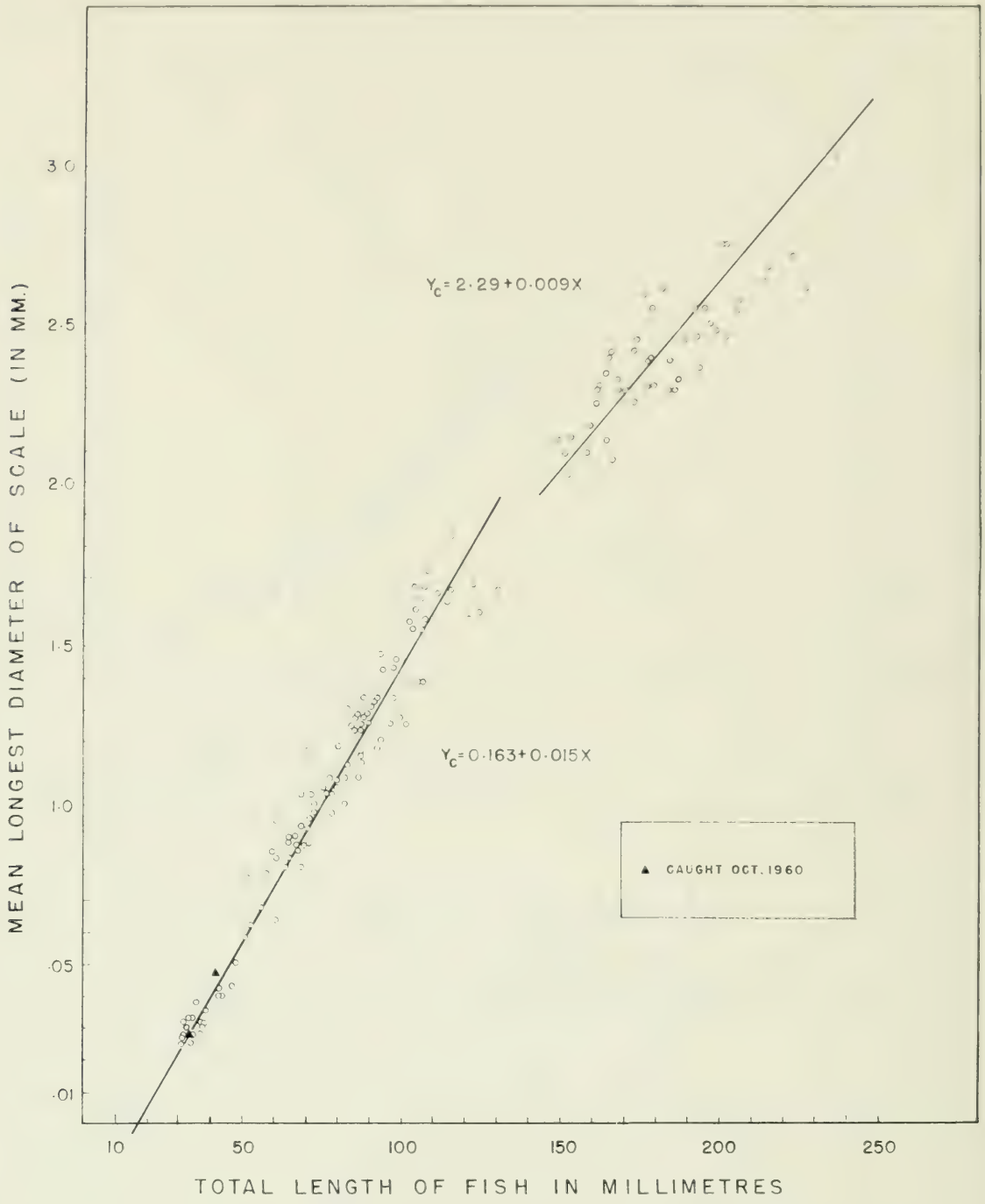


Fig. 10. Body length-scale diameter relationship for Jones Creek grass pickerel.

The best description for the data shown is two straight lines, one for the segment 35–131 mm. T.L. and one for the segment 150–238 mm. T.L. These are $Yc = -0.163 + 0.015x$ and $Yc = 2.29 + 0.009x$.

If the lower line is extended to the intercept it indicates that scales probably appear first on pickerel approximately 18 mm. T.L. The lines are straight so that, within each segment, the method of proportionality can be used for back calculation of fish size at previous annuli.

TABLE VI. Age Composition and Age-length Relationship by Sexes for Jones Creek Grass Pickerel

AGE	I	II		III		IV		V		VI		VII	
.	13	11		56		105		48		17		3	
	♂	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
.	13	6	5	26	30	50	55	20	28	7	10	0	3
?.L. mm.	103.4	124.3	139.2	161.8	170.2	175.8	184.9	195.6	207.4	220.3	238.3	—	260.3
ıge of . mm.	85–126	102–131	126–160	141–194	124–205	155–201	124–215	170–235	174–232	196–240	214–269	—	252–269

PARASITES

This analysis is based on the examination of 15 preserved specimens collected from Jones Creek in the vicinity of Blue Mountain in July and August 1961. There were nine males and six females from 48–187 mm. F.L.

The Gills

Saprolegnia parasitica, Coker, glochidia and large numbers of ciliated protozoans of the families Vorticellidae and Scyphidiidae were present on the gills.

Davis (1953) recently reported *Scyphidia micropteri* from largemouth bass, smallmouth bass and it is known also to occur on frogs. The arrangement is commensal rather than directly parasitic but large numbers occurring in the gills can cause major difficulty to the fish. The scyphiids on the grass pickerel were probably *Scyphidia micropteri* but a positive identification was not possible.

The Digestive Tract

Three species of trematodes were present: *Macroderoides flavus*, Van Cleave and Mueller; *Azygia angusticauda*, (Stafford) and *Centrovarium lobotes*, (MacCallum).

In addition one immature stage of the cestode, *Proteocephalus pinguis*, La Rue and one nematode *Spinitectus gracilis*, Ward and Magath were found.

The Reproductive Organs

The eggs and connective tissues were heavily infected with sporozoan cysts of the order Myxosporidia.

The Urinary System

Several grass pickerel showed heavy infestations of *Trichodina renicola*, Mueller (Family—Vorticellidae). The infestations usually extended into the kidneys.

Skin and Fins

"Black grub" was present on several specimens. Dissection showed the metacercariae to be *Crassiphiala bulboglossa* Van Haitsma.

Only the protozoan parasites appeared dense enough to have endangered the well being of the fish.

TABLE VII. Summary of Parasitism in the Grass Pickerel from Jones Creek, Leeds County

Parasites	Number Infected Fish	Parasite Concentration Index[a]	Location in Host
I Fungus			
1. *Saprolegnia parasitica*	1	light	gills
II Protozoa			
2. Myxosporidia	4	light	reproductive organs
3. *Scyphidia micropteri*	6	heavy	gills
4. *Trichodina renicola*	4	heavy	urinary bladder and kidney
III Trematodes			
5. *Macroderoides flavus*	10	medium	intestine
6. *Azygia angusticauda*	5	light	stomach
7. *Centrovarium lobotes*	5	light	intestine
8. *Crassiphiala bulboglossa*	4	light	skin and fins
IV Cestodes			
9. *Proteocephalus pinguis*	1	light	intestine
V Nematodes			
10. *Spinitectus gracilis*	1	light	intestine
VI Mollusca			
11. Glochidia	1	light	gills

[a]light—1–9 parasites present; medium—10–49 parasites present; heavy—over 50 parasites present.

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Figure 2 was drawn by Karl Pogany.

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